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Academic Knowledge Transfers and the Structure of International Research Networks

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Academic Knowledge Transfers and the Structure of International Research Networks[1]

1. Introduction

Empirical research on academic knowledge transfers has been brought to the center of interest in economics since the end of the 1980s for two main reasons. First, the emerging literatures of the new economic geography (Krugman 1991) and the endogenous growth theory (Romer 1986, 1990) pointed to the need of empirically testing the existence and significance of knowledge spillovers. The second reason is related to the growing interest in the mix of policies that are most suitable to generate "university-based regional development" experienced first in Silicon Valley or in Route 128 (Isserman 1994, Reamer, Icerman and Youtie 2003). Within the academic knowledge transfers literature the geographical dimension has received a particular attention. Studying localized knowledge spillovers as one type of agglomeration economies fits well into the research agendas of both theoretical and empirical economists while the potential of geographically constrained knowledge transfers to contribute to the development of regional economies makes the issue relevant for policy practitioners.

The spatial extent of university knowledge transfers and the factors that determine the degree to which academic knowledge flows into regional industrial applications have been widely researched in the last two decades (see Varga 2002 and Goldstein 2008 for reviews). To investigate the geography of university knowledge transfers two approaches have been developed in the literature: location studies and direct technology transfer studies. Case studies, surveys, descriptive studies and econometric analyses evidence that the effect of universities on the location of high technology activities is not constant over spatial entities and firms but vary according to industrial sectors, ownership status of firms, firm size, and city size (e.g., Malecki and Bradbury 1992, Florax 1992, Audretsch and Stephan 1996, Sivinatidou and Sivinatides 1995). Studies directly investigating the geography of knowledge transfers report that knowledge from universities tends to spill over locally with definite distance decay (Jaffe, Trajtenberg and Henderson 1993, Feldman 1994a, Audretsch and Feldman 1996, Varga 1998, Acs, Anselin and Varga 2002). This finding supports what is hypothesized about the localized nature of tacit knowledge transmission however notable differences across industries are also reported.

Although the majority of the literature on academic knowledge transfers focuses on the geographical aspects several recently published papers raise the issue that besides pure spatial proximity to an academic institution some additional factors (such local culture determining the extent of collaboration and the level of entrepreneurship or the spatial concentration of the system of innovation) might also be instrumental. Understanding the significance of those factors in regional economic development is at least as important for designing effective regional policies as improving our knowledge on the spatial proximity issue. Among the factors influencing academic knowledge transfers the specific role of scientific networking has not been touched upon very extensively in the literature. Scientific networking that may

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take different forms such as collaborative projects, co-publications or less formal meetings in conferences, workshops or seminars is a common means of advancing science, mutual learning, information sharing and gaining and maintaining attention among fellow scientists. Increasing specialization and competition in research as well as the rapid development of technologies that ease sustaining and expanding linkages among scientists over large geographical distances make it both possible and inevitable that collaboration among researchers working in different institutions has become a key to high level research productivity.

Research networking strengthens not only scientific productivity but also academic knowledge transfers to the industry. It is emphasized in the survey of Franzoni and Lissoni (2008) that scientific excellence and success in academic knowledge transfers (in the forms of patenting or spin-off firm foundation) do not necessarily contradict to each other as successful academic entrepreneurs come disproportionately from the class of researchers with a brilliant scientific record. It has also been suggested in the literature that universities may act as key nodes channeling scientific-technological knowledge accumulated in (national or international) research networks to the regional industry via different mechanisms of localized knowledge flows such as patenting, licensing, spin-off firm formation, consulting or participating in collaborative R&D projects (Goldstein, Maier, and Luger, 1995) .

Thus embeddedness in (regional, interregional or international) research networks may make a difference across universities with respect to their success in transferring knowledge to innovations. Ceteris paribus the same amount of university research expenditures might result in different levels of knowledge flows from academic institutions depending on how well they are integrated in scientific networks. Therefore the research question about the extent to which scientific networking influences academic knowledge transfers is indeed a relevant one. A major reason why the impact of research networking on academic knowledge transfers had not been tested systematically until very recently is that econometric estimations suffered from a technical barrier. Spatial econometric models with specific weights matrices (such as inverse distance weights as were done e.g., in Anselin, Varga and Acs, 1997) had been the only possibilities until the rapid diffusion of Social Network Analysis (SNA) methods in innovation research (see Coulon 2005 and Ozman 2006 for reviews on the SNA literature of innovation research). As such SNA applications paw the way of more precise analyses.

The issue of the effect of research networks on academic knowledge transfers has been investigated in some recently published studies with the application of SNA methodologies. Based on their analysis with data on 109 European regions at NUTS 2 level Maggioni, Nosvelli and Uberti (2006) argue that participation in EU 5th framework projects has a positive impact on regional innovation activity while Ponds, Oort and Frenken (2007) report significant interregional research networking effects on patenting using regional data of the Netherlands.

None of these recent studies addresses the question of the role of network structure in academic knowledge transfers. Nevertheless, the particular configuration of networks could make a difference in innovation as reported in several papers on industry networks. For example, Valente (1995), Cowan and Jonard (1999) and Spencer (2003) point to the significance of network structure, Ouimet, Landry and Amara (2004), Morrison and Rabellotti (2005) and Giuliani (2007) emphasize the role of network position, Giuliani (2004) finds that network density, strength of ties and external openness matters in innovation, while Ahuja (2002) reports that structural holes decrease innovation output.

Isn't it a realistic hypothesis that additional to the pure size of research networks other structural features (such as the extent to which the network is concentrated around some "stars" of the scientific field or the intensity of research relationships within the network) are also instrumental in academic knowledge transfers? While the size effect has already been investigated in the literature a more detailed analysis of the impact of network structure is still missing. We address the role of international network configuration in academic technology transfers with the application of recently collected data on international publication networks of selected research units at the University of Pécs. The second section explains the data, develops indices for different network characteristics and designs a comprehensive measure of academic network quality. In the third section (based on an extended knowledge production function framework) the effect of international network structure on university patenting is tested. We conclude with a summary section.

2. The structure of international publication networks

It is hypothesized in this paper that structural features of research networks of universities are significant factors in knowledge transfers. Thus, ceteris paribus even with similar levels of research expenditures universities may generate different economic impacts through knowledge transfers depending on the structure of their (regional, interregional or international) scientific networks. How can we define those network characteristics that are instrumental in knowledge transfers and how can we measure them? Can we even summarize those features in one particular index? These issues are in the focus of this section.

While determining important network features in academic knowledge transfers our starting point is the systems of innovation (SI) literature (e.g., Lundvall 1992, Nelson 1993). According to this literature production of economically useful new knowledge depends to a large extent on three system characteristics: the number of actors involved in the system, the knowledge those actors have accumulated and the intensity of knowledge-related interactions among the actors during knowledge creation. Thus the efficiency of research networks in producing new knowledge can be approached by three features: the size of the network, the professional knowledge of individual scientists involved in the network and the frequency of their interactions (e.g., research collaboration, mutual learning).

We argue in this paper that the quality of research network connections influence the scientific productivity of individual network members and as such academic knowledge transfers. How can we define the quality of a network connection and what are the structural features of a research network that determine it? Quality of a network connection reflects the level of knowledge (both tacit and codified) and information to which the individual researcher gets access by being linked to the network. This depends on the knowledge accumulated in the network and the position of the individual scientist within that network. Thus the knowledge to be accessed is related to the size of the network, the knowledge the members of the network possess, the intensity of science related interactions among the actors and the network position of the individual researcher. Larger size, higher levels of knowledge of network members and frequent interactions among them are essential to guarantee the continuous extension of knowledge within the network (as described in details by the SI literature) whereas network position could be extremely important for accessing that knowledge.

Research network position is either related to the knowledge (and reputation) of the researcher or to the knowledge (and reputation) of the immediate network partner of the researcher. There is a simultaneous relation between individual knowledge of the researcher and the number of linkages the researcher possesses in the network. Higher knowledge levels increase reputation that (via increased visibility) opens the possibilities for researchers to further increase the number of connections within the network whereas increased number of linkages let them access and produce even higher levels of knowledge. Moreover it is also assumed that a favorable position in the network positively affects the position of the researcher's immediate network partner as well first by providing him or her access to a considerable portion of knowledge accumulated in the network (and concentrated by the researcher with high reputation) and second (through more visibility) by offering good opportunities for increasing the number of his or her own connections. Therefore a researcher even with a lower level of scientific output can get access to high level of knowledge (which may lead to increased research productivity) in case the immediate partner enjoys considerable reputation.

Thus the advantage of a better quality network connection is that it increases research productivity both directly (with higher probabilities of achieving truly relevant results in collaboration) and indirectly (through learning and building further connections). As such the size of the research network, the intensity of knowledge related linkages and the knowledge level of researchers (especially the knowledge of the immediate network partner) characterize network connection quality.

To study empirically the effect of research networks on academic knowledge transfers we use co-publication data collected for selected academic units at the University of Pécs (UP). We assume that the quality of international research network connection of each scientific unit (represented by international co-publications) influences knowledge transfer activities of those academic units. The selection criterion was international publication excellence in hard sciences relative to the usual level of university research units at UP in these fields. The chosen year is 2000. UP Library and the ScienceDirect and EBSCOhost publication databases were the sources of data. Our focus is on those networks to which UP researchers are connected hence we collected data on research networks of international co-authors of each UP researcher in the sample. Table 1 lists the main features of the co-publication networks aggregated to academic units.

The international co-publication network to which each UP academic unit is connected is described by the numbers of UP scientists and their immediate research partners and the number of coauthors of the immediate international research partners. The size of research networks exhibits a considerable variation as demonstrated in Table 1. The internal structure of each network shows an even higher variability. This can be studied in Figures 1 to 3. Black triangles stand for the immediate research partners of UP scientists whereas their network members are shown by black squares (Hungarian coauthors) and circles (international coauthors). According to the simultaneous relationship between academic excellence (i.e., the knowledge of individual researchers) and the extent to which a researcher is connected with others in the network the number of links of an individual scientist represents academic reputation. Our data allow us to judge network positions of UP researchers as well as their immediate publication partners. Since in none of the networks investigated UP researchers play a central role our analysis concentrates on the network positions of UP coauthors, the size of the network and the level of interactions within the network.

Table 1 Selected features of international co-publication networks of sample University of Pécs academic units, 2000

	International publications	UP coauthors	International coauthors of UP faculty	International coauthors of the international coauthors of UP faculty
Clinic of Neurology	4	2	19	152
Department of Anatomy	18	11	6	102
Department of Biophysics	7	6	7	54
Department of Immunology and Biotechnology	4	3	13	77
Department of Medical Chemistry	7	9	31	191
Department of Medical Genetics and Child Development	3	1	6	92
Department of Medical Microbiology and Immunology	5	5	15	251
Department of Neurosurgery	5	5	10	145
Department of Orthopedics	7	8	12	53
Department of Pathology	6	7	9	141
Department of Pediatrics	12	8	9	169
Department of Pharmacology and Pharmacotherapy	4	1	2	23
Department of Surgery	3	3	10	136
Institute of Organic and Medicinal Chemistry	3	2	4	57
Institute of Physics Department of Experimental Physics	10	3	17	104
Institute of Physics Department of Theoretical Physics	6	6	9	28

Network connection quality of individual research units varies widely in the sample. Some of the network connections might be described as “poor” such as the one of the Department of Pharmacology and Pharmacotherapy (Figure 3) where the two immediate international coauthors show modest levels of reputation (indicated by the number of their linkages) while the intensity of collaboration is also at a low level in the network (indicated by the linkages connecting members of the network). To take another example consider the Institute of Organic and Medical Chemistry (Figure 3) where one of the immediate international publication partners has several linkages but the small size of the network and also the rare occurrences of interactions among the partners (i.e., each paper is an “island” with no “bridges” among them) set the quality at a relatively low level.

On the other hand, the Department of Pediatrics (Figure 1) with the large size of the network it is connected to, the very intense collaboration among network members and the high concentration of linkages at some of the immediate research partners (who might even be “star scientists” of their field) possesses a high quality network connection.

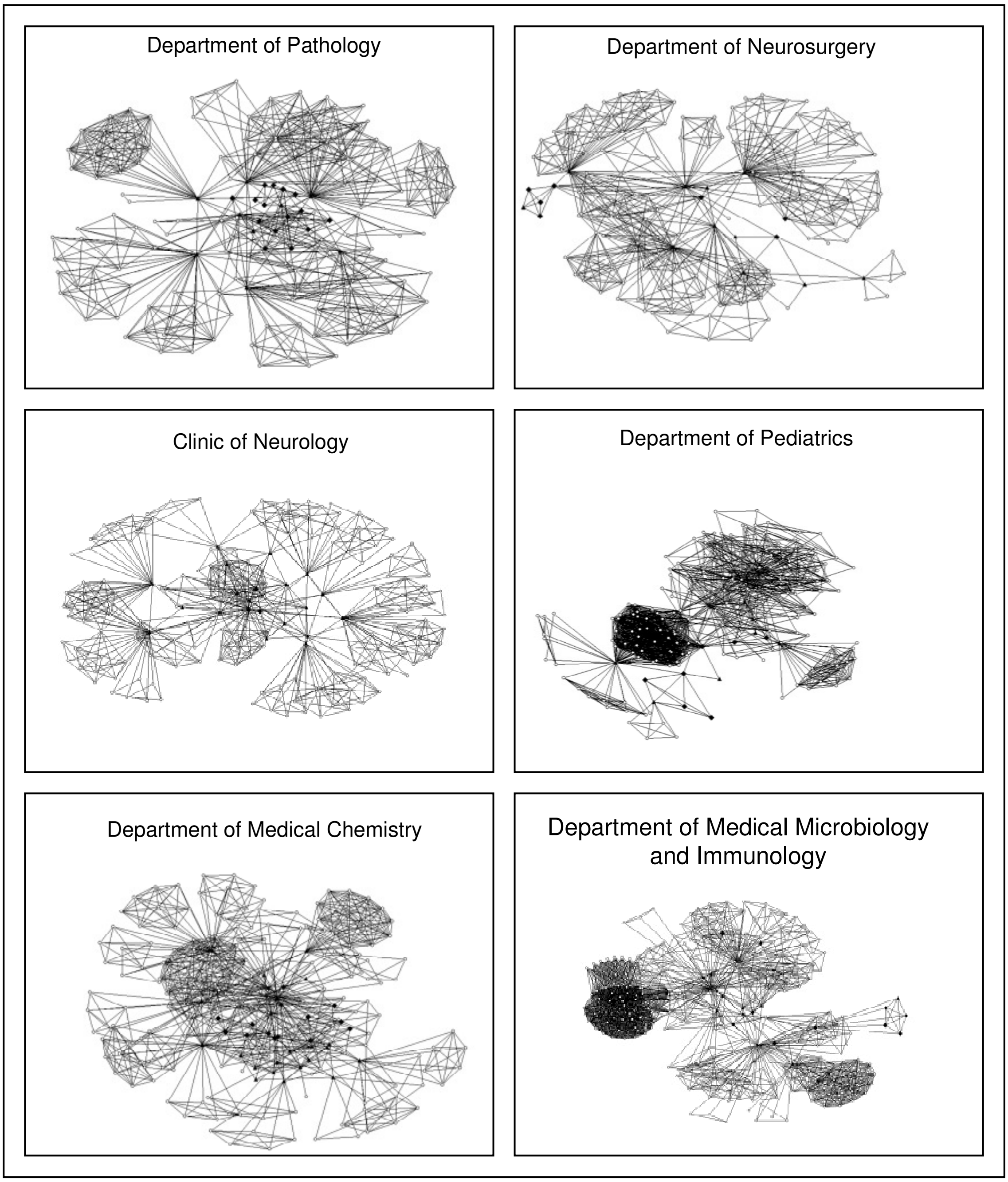

Figure 1 Large international networks

Note: Black triangles stand for the immediate research partner of UP scientists whereas their network members are shown by black squares (Hungarian coauthors) and circles (international coauthors).

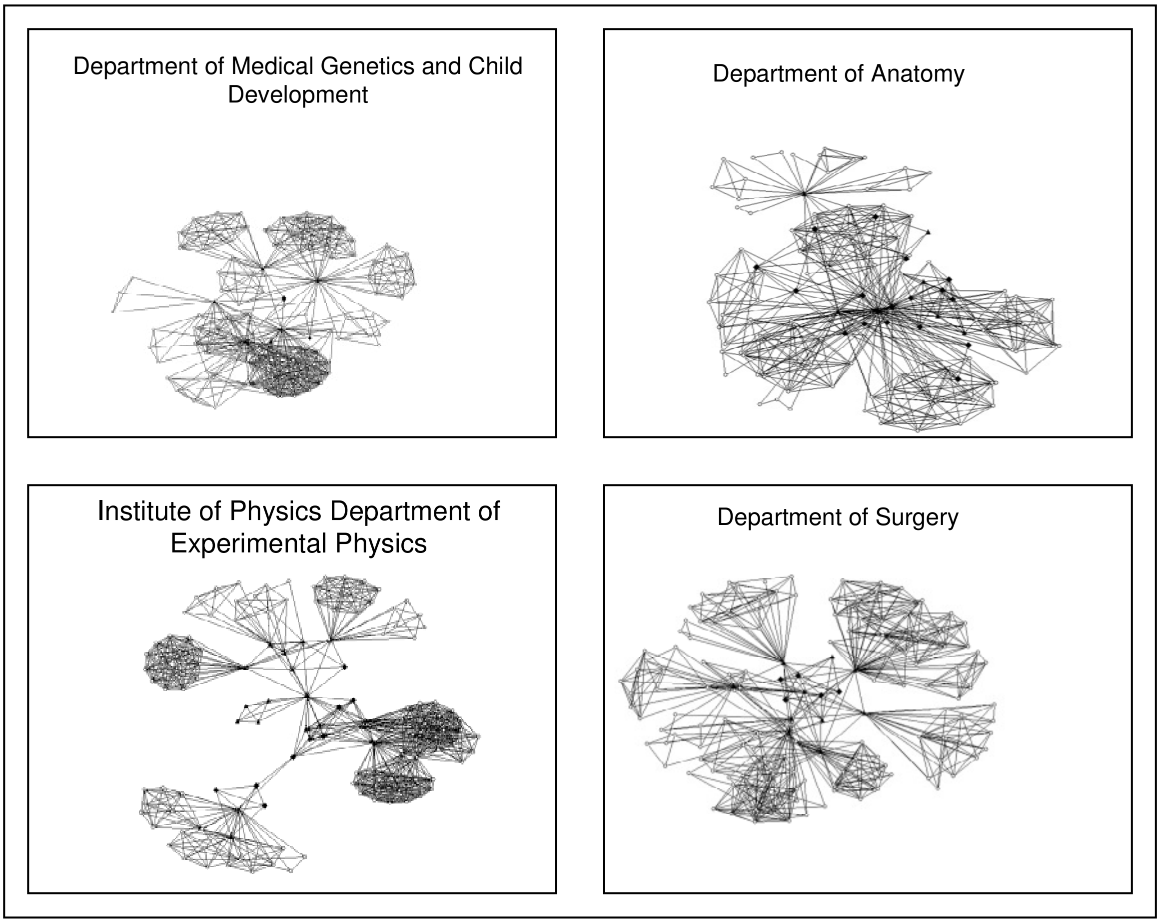

Figure 2 Medium size international networks

Note: Black triangles stand for the immediate research partner of UP scientists whereas their network members are shown by black squares (Hungarian coauthors) and circles (international coauthors).

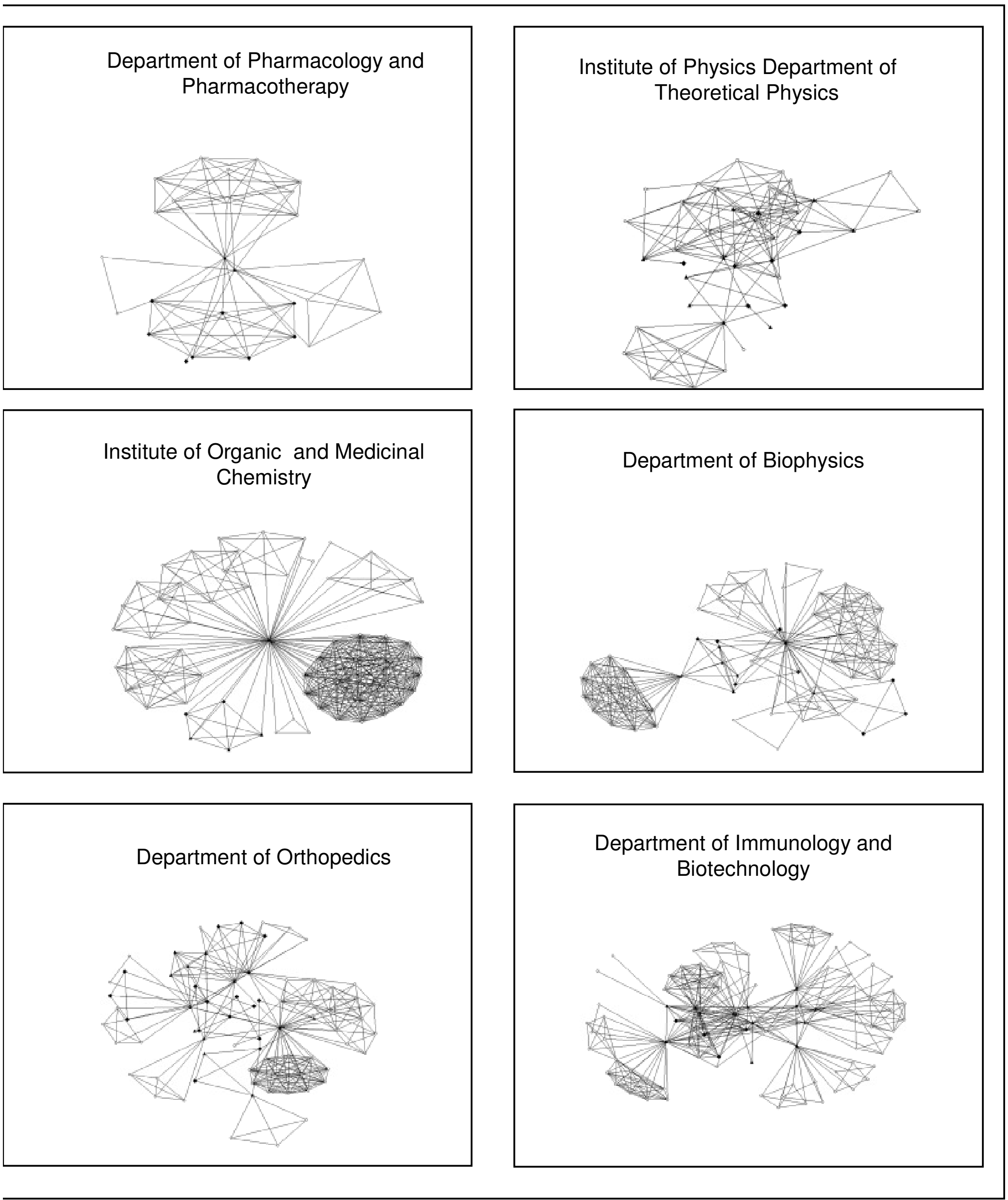

Figure 3 Small international networks

Note: Black triangles stand for the immediate research partner of UP scientists whereas their network members are shown by black squares (Hungarian coauthors) and circles (international coauthors).

In order to study the effect of network connection quality we need to quantify those structural features that are instrumental in determining it. Since the measures to be used in the current analysis should be comparable across networks with different sizes commonly applied indices such as centrality (which could be useful for measuring reputation) or density (for quantifying he intensity of network connections) are not suitable (Scott 2000). As such appropriate indices need to be developed before studying the network effect on knowledge transfers.

To measure the size of the network of academic unit i we introduce the following index:

$SIZE_i$ = (Network members)$_i$/(Network members)$_{max}$

Thus the values of SIZE are between 0 and 1 where the academic unit with the largest network gets the value of 1.

As shown in Figures 1-3 network position of UP international publication partners could be decisive while network connection quality is determined. How to measure this position? We start with the experience that the knowledge of a researcher determines his or her position in a scientific community and this position is reflected by the number of linkages the researcher possesses. Thus the better the network position of a scientist the more concentrated the network around him or her. The following formula calculates the index of knowledge concentration by immediate research partners of each academic unit:

$CONC_i$ = (average number of international coauthors of immediate UP coauthors)i/(average number of international coauthors of immediate UP coauthors)max

The values of CONC range between 0 and 1. The higher the value of CONC is the better the average position of UP publication partners of a research unit.

The index INT measures the level of integratedness of the network. By integratedness we intend to quantify the intensity of linkages among network members.

INT_i = [(Average number of linkages on a paper)/(average number of linkages among coauthors on a paper)]$_i$/[(Average number of linkages on a paper)/(average number of linkages among coauthors on a paper)]$_{max}$[2]

The higher the value of INT is the larger the relative number of linkages bridging communities of coauthors of different papers. Hence INT measures the intensity of interactions among network members and its value ranges between 0 and 1.

Figures 4-6 present the values of SIZE, CONC and INT for the studied publication networks classified into the three network size categories.

[2] The average number of linkages per paper measures the linkages among authors. It is calculated in the following manner: N*(N-1)/2, where N is the average number of coauthors on a paper. The average number of linkages on a paper is the ratio of the size of the network and the number of articles.

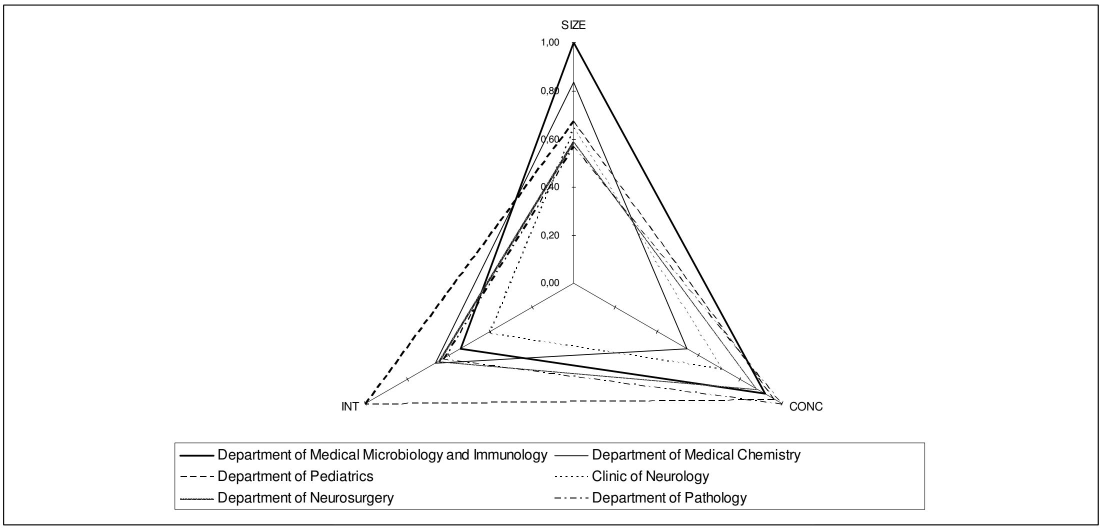

Figure 4 SIZE, CONC, INT: Large international networks

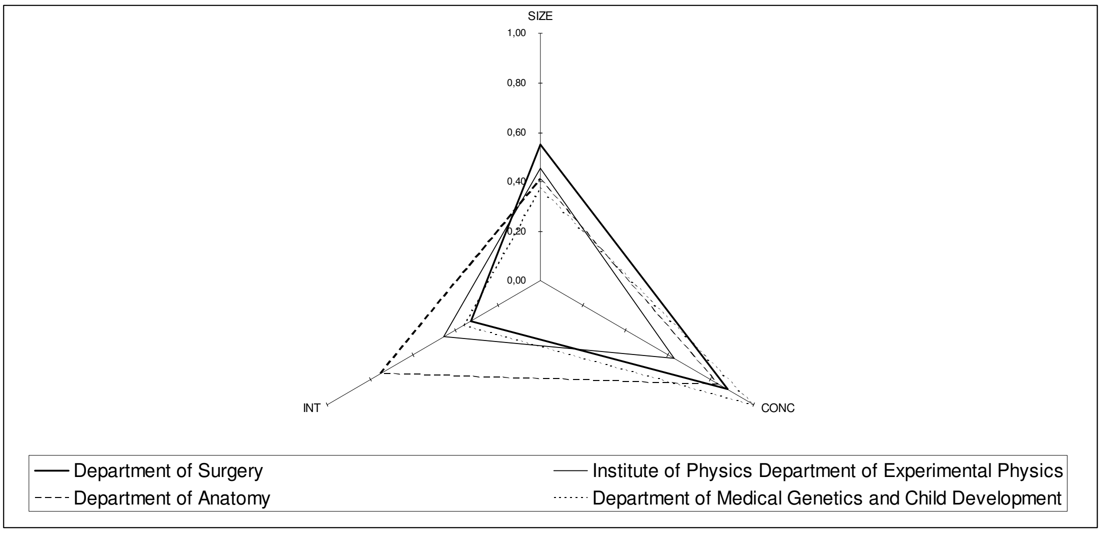

Figure 5 SIZE, CONC, INT: Medium size international networks

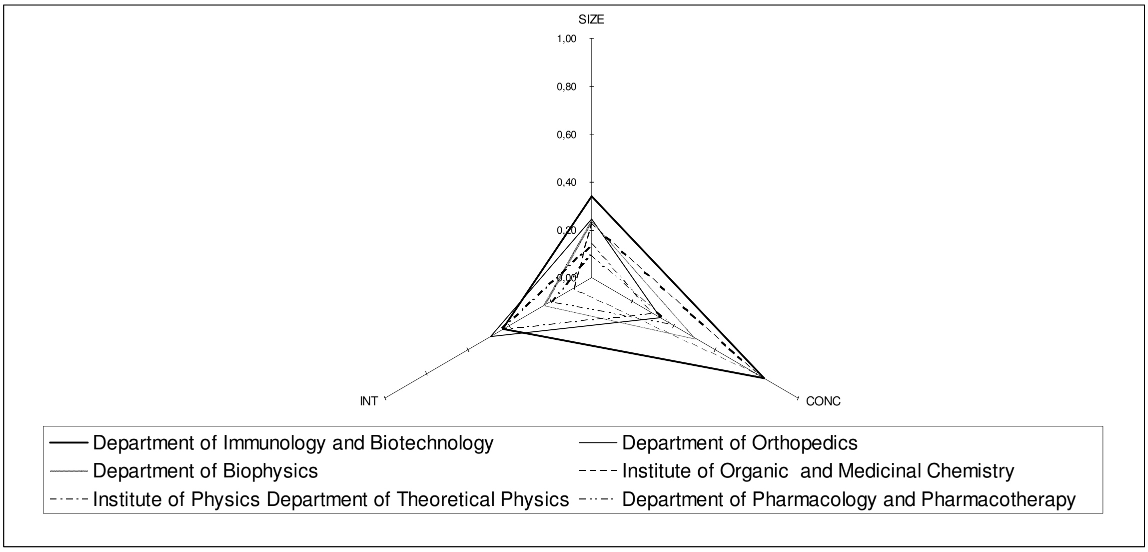

Figure 6 SIZE, CONC, INT: Small international networks

A comparison of patterns in Figures 1-3 and 4-6 suggests that the three measures follow the three network characteristics very closely.

The quality of a network connection reflects the three structural characteristics and is in a positive relationship with all of them. How could we integrate the three indices into one to measure network connection quality? The intuition behind the solution comes after studying the triangles of Figures 4-6: the composite quality index (NETQUAL) for each academic unit is the area of the respective triangle representing the unit divided by the maximum possible area of the triangles. Thus the closer the value of NETQUAL is to 1 the higher the quality of network connection of an academic unit resulting from a particular combination of SIZE, CONC and INT. Figure 7 exhibits NETQUAL values.

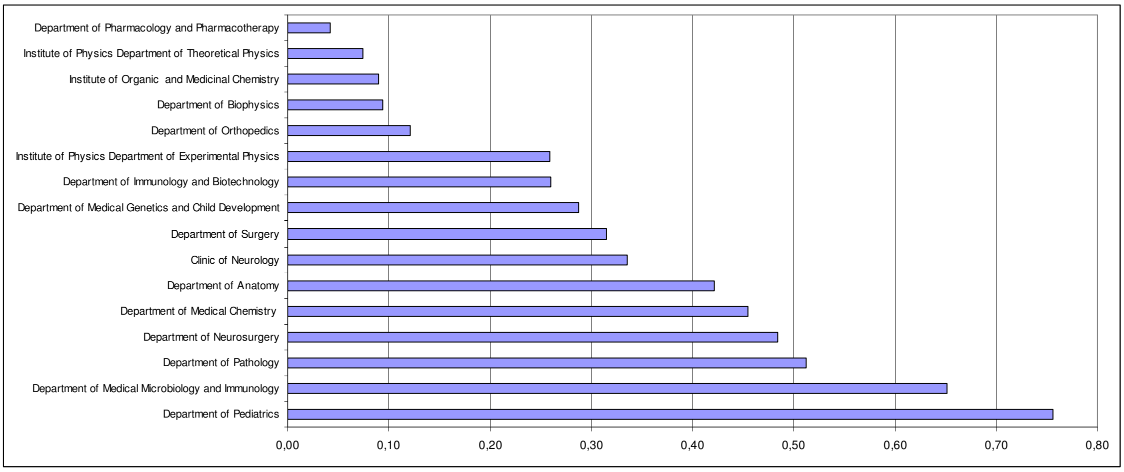

Figure 7 NETQUAL values by UP academic units

3. Empirical model, data and results

Expenditures on research and development are key determinants of scientific success. While modeling university knowledge transfers R&D expenditures are commonly applied input measures in empirical studies. However, even with expenditures at similar levels the impact of university research could be different depending on various factors such as the development of the innovation infrastructure, entrepreneurship or cultural factors like the openness to cooperate in innovation. We hypothesize in this paper that academic technology transfers are also related to the quality of network connections and this effect alters the impact of R&D expenditures.

To empirically test our hypothesis we follow the approach of Varga (2000, 2001) and Acs and Varga (2005) to develop a hierarchical regression framework within the knowledge production function approach of Griliches and Jaffe (Griliches 1986, Jaffe 1989). The empirical model is written in the following form:

$$K_i = \alpha_0 + \alpha_1 RD_i + \alpha_2 Z_i + \varepsilon_i, \qquad (1)$$

where K is economically useful scientific knowledge, RD is research and development expenditures, Z is for additional explanatory variables (such as a variable measuring the experience in industrial problem solving) and ε is the error term. Observational units are groups of university researchers specialized in particular research fields.

We assume that α_1 is not constant across observational units but depends on research network features. Thus the model in (1) is then extended by the following equation:

$$\alpha_{1,i} = \beta_0 NET_i, \qquad (2)$$

where NET_i stands for a particular characteristic of the research network of observational unit i. Therefore to account for the impact of networking the estimated equation gets the following form:

$$K_i = \alpha_0 + \beta_0 NET_i\, RD_i + \alpha_2 Z_i + \varepsilon_i, \qquad (3)$$

In the following empirical analysis we study the impact of research networking on university patenting a particular type of academic knowledge transfers. Data come from two sources. The first is the publication database of UP academic units that has already been explained. The second data source is a result of a survey of UP research groups conducted in 2006 (Szerb and Varga 2006). Table 2 explains the data in details.

Reflecting the fact that K in (1) is measured by count data we run negative binomial count regressions. Estimation results are presented in Table 3. According to expectations R&D expenditures enter the equation with a positive and significant parameter (M1). The effect of experience in industrial problem solving (measured by the number of collaborating firms) matters for the case of Hungarian firms but not for international companies (M2 and M3). One of the pharmaceutical research groups (Pharma 1) shows exceptionally successful knowledge transfer activities (5 accepted patents) during the time period under consideration. To account for potentially different mechanisms of knowledge production at this group we introduced the PHARMA1 dummy.

Table 2 Description of the applied data

Variable	Explanation	Number of research groups**	Minimum	Maximum	Average	Standard deviation
PATANUM*	Number of university patents (2000-2005)	23	.00	5.00	.39	1.16
PROJBUD17	The value of the seven most important projects in Euro (2000-2005)	23	50 000	3 701 000	894 000	1 144 000
CONC	Knowledge concentration (year 2000)	23	.29	1.00	.66	.25
INT	Intensity of interactions (year 2000)	23	.09	1.00	.47	.21
SIZE	Network size (year 2000)	23	.09	1.00	.46	.28
NETQUAL	Network connection quality (year 2000))	23	.04	.76	.32	.21
COBHNUM*	Hungarian firms collaborating in innovation (2000-2005)	23	.00	5.00	1.74	1.36
COBFNUM*	International firms collaborating in innovation (2000-2005)	22	.00	2.00	1.09	1.02

Notes: * medium of the range
** A particular academic unit might contain several research groups. This results in different observation numbers in Tables 1 and 2.

Table 3: Negative Binomial Count estimation results for the Number of University Patents, selected University of Pécs hard sciences research groups, 2000-2005

	M 1	M 2	M 3	M 4	M 5	M6	M 7	M8	M9	M 10	M11
C	-2.866***	-6.025**	-6.983**	-5.916**	-2.715***	-7.797**	-4.062***	-8.209*	-2.943***	-6.369**	-8.695
	(0.914)	(2.642)	(3.548)	(2.596)	(0.996)	(4.048)	(1.403)	(4.670)	(1.059)	(0.027)	(5.392)
PROJBUD	1.01E-06***	1.30E-06***	1,17E-06**	9.89E-07*							
	(3.33E-07)	(5.04E-7)	(4.93E0-7)	(5.51E-07)							
PROJBUD*SIZE					1.02E-06	2.42E-06*					
					(6.65E-07)	(1.29E-06)					
PROJBUD*CONC							1.52E-06**	1.73E-06*			
							(6.70E-07)	(9.75E-07)			
PROJBUD*INT									1.14E-06*	1.70E-06*	
									(6.10E-07)	(8.99E-07)	
PROJBUD*NETQUAL											3.27E-06*
											(1.96E-06)
COBHNUM		0.991*		1.014*	0.581	1.479*	0.752**	1.532*	0.575*	1.166*	1.685
		(0.564)		(0.549)	(0.325)	(0.833)	(0.376)	(0.931)	(0.335)	(0.620)	(1.092)
COBHNUM+COBFNUM			0.861								
			(0.537)								
PHARMA1				1.838		5.606**		4.350**		4.429***	6.426**
				(1.520)		(2.346)		(2.030)		(1.675)	(3.183)
LR-Index (Pseudo R^2)	0.34	0.45	0.45	0.50	0.14	0.56	0.31	0.57	0.18	0.52	0.58
Log Likelihood	-12.766	-10.41	-10.19	-9.604	-16.285	-8.409	-13.047	-8.174	-15.556	-9.198	-7.999
N	23	23	22	23	23	23	23	23	23	23	23

Notes: estimated standard errors are in parentheses; *** is significance at 0.01, ** is significance at 0.05; * is significance at 0.10.

Our base model is M4. Compared to M2 model fit increased somewhat in M4 (the LR index[3] went up from 0.45 to 0.50) but the parameter of PHARMA1 is not yet significant. Models M5, M7 and M9 estimate the impacts of network characteristics in focus such as network size (SIZE), knowledge concentration (CONC) and intensity of research collaboration (INT). M6, M8 and M10 have the same setups but treating Pharma 1 separately. In general we found marginally significant effects of network features ($P<0.10$). It is also evidenced that Pharma 1 follows a different pattern from the rest of the research groups. The PHARMA1 dummy enters the models with significant and positive parameters. Additionally, introduction of this dummy variable increases regression fit considerably. M11 shows that the effect of network connection quality on university patenting is also positive and marginally significant ($P<0.10$). This model provides the best fit to the data which is an important further evidence for the network quality effect.

Regression results support the hypothesis that the impact of academic R&D expenditures on knowledge transfers varies according to the quality of research network connections. To what extent this impact differs across research units? Which network characteristics have the strongest influence on the quality effect? The next step in the analysis is to answer these questions.

Substituting the estimated β_0 from M11 to (2) and calculating $\alpha_{1,i}$ for each research unit result in the Alpha NETQUAL values of Figure 8. The Figure demonstrates that the impact of R&D expenditures on university patenting shows notable variations across academic units depending on their network connection quality. The straight line indicates the value of α_1 as estimated in M4. This parameter shows the average effect of R&D on university patenting with no respect on the differences in network connection quality. On the other hand, Alpha NETQUAL varies widely: there is 18 times difference between the minimum and the maximum estimated values of $\alpha_{1,i}$.

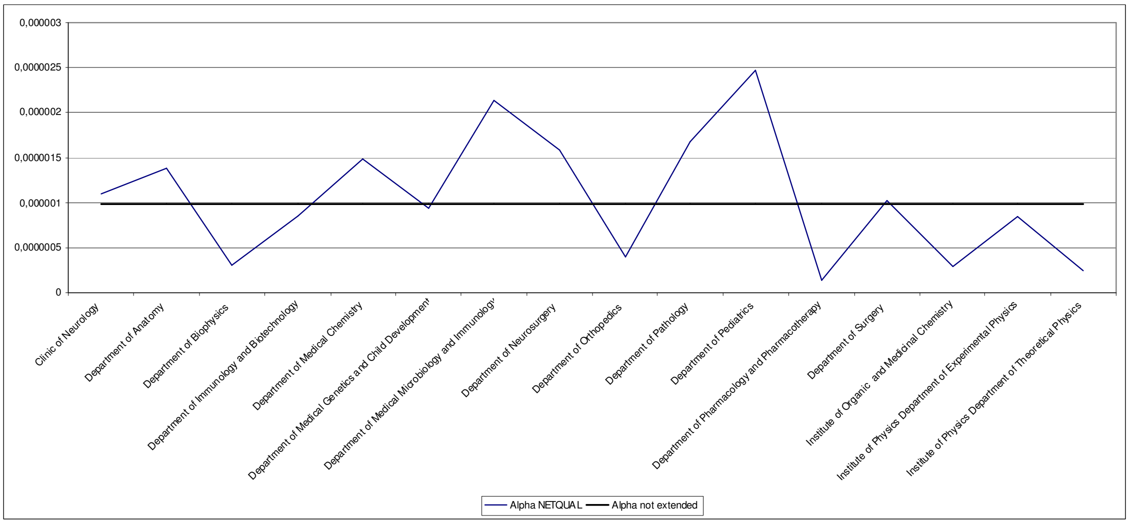

Figure 8 The influence of network quality: Varying R&D expenditure impacts on university patenting

[3] The LR index relates Log-likelihood values of the estimated equation with constant term only to its actual version.

Table 4 The effect of network characteristics on the network connection quality parameter, (Log(α_1))

Constant	12.512*** (0.392)
Log(BETACONC)	0.709*** (0.033)
Log(BETAINT)	0.568*** (0.023)
Log(BETASIZE)	0.635*** (0.024)
R^2	0.998
N	23
F-statistic	3467.506***

Note: estimated standard errors are in parentheses; *** is $p < 0.001$

Can we weight the impacts of different network characteristics on the network connection quality effect? The regression output in Table 4 evidences that the position of the immediate coauthor in the research network (measured by the concentration of knowledge by the international partner) is the most influential network characteristic to determine the differing effects of R&D on university patenting. The estimated parameter indicates that a 1 percent change in CONC results in a 0.71 percent average change in the estimated α1 values of the research units. This is followed by the size of the network and the intensity of collaborations among researchers in the network.

4. Summary and conclusions

Transfers of economically useful scientific knowledge from universities to industry could generate substantial economic growth as the experiences of classical high technology regions (e.g., Silicon Valley) and emerging new technology centers around the World well demonstrate this effect. It is evidenced in the literature that the effectiveness of academic knowledge transfers is related to several factors. Our study focuses on the role of research network connection quality in this respect. Research network connection quality determines the stock of knowledge to which the individual researcher has access by being linked to other researchers. It is related to the knowledge accumulated in the network and also the position from which the researcher enters the network.

Applying recently collected data on international publication networks of selected hard sciences research units of the University of Pécs this paper analyzes the effects of network size, concentration of knowledge at immediate international publication partners and intensity of interactions among network members on university patenting. The main achievements of this study can be summarized as follows:

the term “network connection quality” is introduced to estimate the impact of research networks on academic knowledge transfers;

- appropriate indices measuring size and concentration of networks and interaction intensity among network members are developed;
- a composite index of network connection quality is introduced;
- the effects of individual indices of network structure characteristics and the composite network connection quality index on university patenting are estimated within the knowledge production function tradition;
- the importance of individual network characteristics for the impact of network connection quality is tested.

Our results indicate that the quality of international network connections matters for academic knowledge transfers. Thus not only the distribution of public research expenditures across different research projects is important but also the position from which researchers enter international networks and the level of knowledge accumulated in those networks. The main policy consequence of this study is that the set of tools of knowledge based economic development should include not only R&D promotion but also clever ways of supporting academic research networking. For the University of Pécs it is found that promoting connections to higher position international scientists would be the most advantageous way of strengthening the network quality effect on university patenting.

We need to mention the limitations of the current study. These include first that we collected only one year of publication network data. More years would perhaps alter our results. Also we were not able to account for the scientific quality of publication partners of immediate international colleagues of UP researchers. Although this would not change our results with respect to the examined network structure characteristics its impact on the overall quality of network connections might be interesting. Future research based on data collected for several universities will certainly extend our knowledge on the relationship between research networks and academic technology transfers even further.

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